Positive Industrial Policy: The Implications for R & D

Policy
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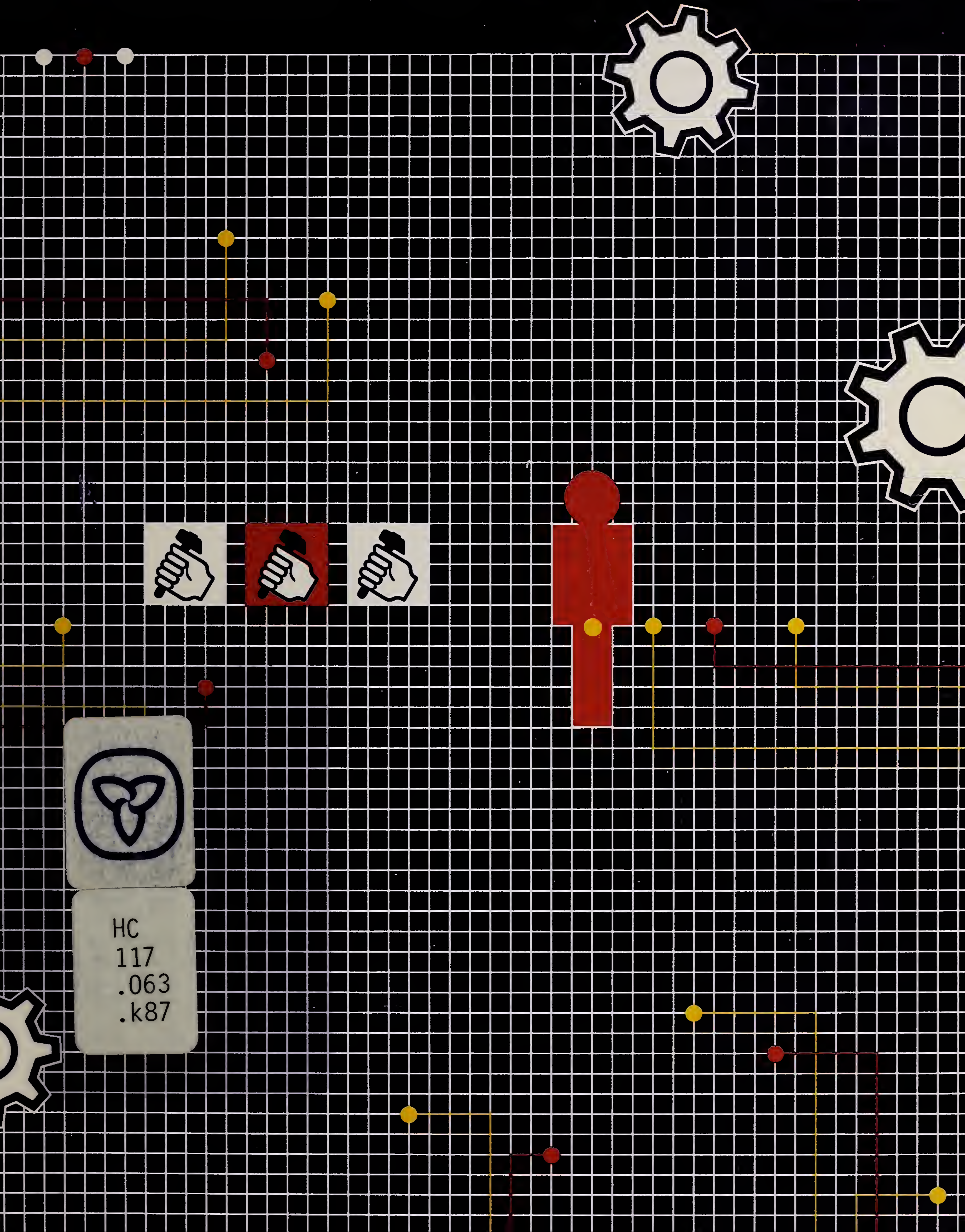
Series

Yehuda Kotowitz



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POSITIVE INDUSTRIAL POLICY: THE IMPLICATIONS FOR R&D

Positive Industrial Policy: The Implications for R&D

Policy
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Ontario
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Yehuda Kotowitz

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Preface

This is the fifth in a series of studies on industrial policy prepared for the Ontario Economic Council, under the auspices of the Institute for Policy Analysis of the University of Toronto by a group of researchers at the University of Toronto and McGill University headed by Richard M. Bird and Christopher Green. Three studies – William G. Watson's *A Primer on the Economics of Industrial Policy*, Ronald S. Saunders's *Aid to Workers in Declining Industries*, and Christopher Green's *Industrial Policy: The Fixities Hypothesis* – have already been published in the Council's Policy Study Series. A further study – William Milne's *The Interdependence of Macroeconomic and Industrial Policy* – has been completed as will a summary overview of the project as a whole by Richard Bird. Although each author in this series has generally pursued his own line of investigation in his own way, as a whole this collection of studies on different aspects of industrial policy provides a thorough (and in general rather skeptical) review both of much of the burgeoning literature on this subject and of many relevant federal and provincial policies that are now in place or have been proposed.

The author is grateful to his colleagues and anonymous outside reviewers for comments, to the Institute for Policy Analysis for organizing this project, and especially to the Ontario Economic Council for making it possible.

May 1985

Richard M. Bird
Director
Institute for Policy Analysis
University of Toronto

1
Introduction

Industrial policy in Canada has generally followed two avenues – tariff protection and incentive schemes. Both approaches have been used mostly in support of industries that have difficulty competing internationally, such as textiles and shoes. Recently, however, pressures have been mounting to change this policy of propping up losers to one of supporting winners – that is, growth industries in general and those in which we may have a comparative advantage in particular.

Attention has focused mainly on inducements to the private sector to increase applied industrial research and development (R&D) as a means of generating innovation and the expansion of 'high-tech' industries. Proponents of such inducements argue that these industries will grow more rapidly than other industries and hence will generate the best employment prospects for the future. Additional directly supportive measures recommended by the Science Council of Canada and the Senate Special Committee on Science Policies include structural policies designed to promote mergers and co-operative R&D (and thus realize benefits from scale economies – at the possible cost of reduced local competition), direct government entrepreneurial and research activities, tariff and bilateral trade agreements, and the use of government procurement to help local industries.

Such policies are hardly a uniquely Canadian preoccupation. Both the EEC countries and the U.S. have been pursuing many of these policies for some time, and there are signs of increasing government intervention through industrial policy and export promotion in these countries, under the threat of the Japanese challenge. Indeed, Japanese industrial policy is frequently used as an example of a successful interventionist positive policy, one that encourages growth industries through a process of planning, consultation, and financial stimulus to research and development.[1]

Many of the arguments put forward by proponents of interventionist strategies suffer from commodity fetishism and are clearly self-serving. In addition, they fail to describe explicitly the criteria to be used for social choice of policies, frequently relying on the simple observation that social welfare is expressed by the revelation of preferences through the political process. However, this argument is hardly satisfactory, since it does not yield any substantive grounds for the economic evaluation of policies.

It is, nonetheless, possible to make a 'prima facie' rational case for government intervention on economic grounds. The purpose of the present paper is to set out some of the economic arguments for such a policy and to evaluate them in the light of economic theory and evidence. In particular, it is important to note at the outset that our knowledge about some of these issues is extremely limited and cannot safely form the basis for an active policy. Consequently, the relative risks of different forms of intervention and nonintervention must be weighed carefully. In particular, the value of remaining flexible and of avoiding large irreversible commitments cannot be overemphasized.

Chapter 2 briefly analyses the possible economic rationale for government support of R&D. Chapter 3 surveys the evidence on the causal relation between R&D and growth at the national, industry, and firm levels. Chapter 4 discusses the particular advantages attached to priority in innovation, to 'being first'. Finally, Chapter 5 summarizes the evidence and draws a few policy conclusions.

2
An economic rationale for government support

Two questions must be answered affirmatively before government support for industry can be justified from an economic point of view. First, do impediments exist that seriously restrict the ability of the private market to take advantage of all opportunities and therefore to realize the allocation of resources among industries and activities that is optimal from a collective point of view? Second, can the government do better?

Market imperfections relevant to industrial policy arise mainly, though not exclusively, from rigidities that prevent rapid adjustments, from distortions caused by government policies that may not be reversible, and from the existence of public goods and externalities, both pecuniary and nonpecuniary.[2] Let us examine each of these factors in turn.

Some of the main obstacles to the movement of labour and capital from declining to growing industries arise from current government policies that prevent labour markets from adjusting rapidly to sectoral demand changes. These obstacles include tariffs and other assistance to declining industries, minimum wage and other income support policies, and regional equalization payments.[3] Because these policies act to maintain wages and employment in declining industries, or to support the unemployed, they force growing industries to offer higher wages to attract labour and capital from declining industries.

Because capital and labour are, at least in the short run, industry-specific (not easily transferable between industries), the productivity of labour displaced from declining industries tends to be low in many of the new, growing industries, unless significant retraining is undertaken. Indeed, the productivity of displaced labour may be lower than the reservation wage of the unemployed, and it will certainly be lower than the relatively high skilled-labour wage maintained in a declining industry that is under tariff and other protection. Growing industries must therefore both attract workers by offering them higher wages and provide the training needed to raise productivity. However, individual firms do not have an incentive to invest in the training of individuals who may be bid away by their competitors. Government support policies for declining industries also have demand-side effects on growing industries. Moreover, the tariffs and other assistance given to declining industries reduce imports and thus raise the value of the Canadian dollar, an outcome that reduces the profitability of unprotected export- or import-competing industries. Government support policies may thus reinforce the tendency of labour markets towards wage rigidity and towards slow adjustment in terms of mobility and in the acquisition of new skills.

Consequently, unless the government also supports growth industries, in order to enable them to attract workers from declining industries and, in particular, to subsidize their retraining, growing industries will be at a disadvantage relative to declining industries. In periods of rapid change the problem will become even more acute, since, as increasing amounts of human capital depreciate, larger support expenditures will become necessary.

One obvious solution is to eliminate such support for declining industries and regions. However, the distributional consequences would probably be politically unacceptable. Moreover, many of these programs may be desirable, on income distribution grounds, as a form of social insurance. In this context, government support of growing industries may be desirable as a second-best solution designed to alleviate structural unemployment problems caused by labour market imperfections and government social insurance policies.[4]

A second major market failure, one that primarily affects high-technology growth industries, arises from the inadequacy of private incentives for R&D, which in turn arises from the public goods characteristics of information – that is, the fact that its use by one party does not diminish its availability or, possibly, its usefulness to others. It is difficult for the producer of information to appropriate the benefits he has created because he has no means of preventing resale by potential buyers. Moreover, when innovations involve new products, imitation is possible. Thus an innovator in effect confers an externality on other producers, who can imitate the innovation at a cost lower than the cost of the original discovery, or on consumers, who benefit from the lower prices that result from such competition. The private benefits to the innovator, and thus the incentives to invest in the creation of information, will therefore fall short of the social benefits, and the result will be sub-optimal investment in R&D. Because information, once invented, becomes available to everyone, competitors will prefer to free-ride on the efforts of the inventor. It is even possible, under certain circumstances, that everyone will wait for someone else to invent, so that investment and innovation will not occur at all.

The patent system is designed to mitigate this problem by conferring property rights in the innovation on the inventor. It thus ensures greater equality between private and social benefits and improves the incentive to invest in R&D, albeit at the cost of under-utilization of the innovation. However, patent protection is notoriously ineffective, and in many cases it fails to adequately protect private benefits. In fact, because of the disclosure requirements and expense of patents many innovators prefer to rely on secrecy, particularly (though not exclusively) in the case of process innovations.[5] The divergence between private and social returns to investment in R&D depends critically on the ability of the innovator to appropriate the benefits of his efforts. The lower is this ability the greater is the excess of social over private benefits of R&D and the larger is the shortfall of R&D investment relative to the optimal.

This state of affairs is of course not unique to Canada; it provides the basis for R&D support in most countries. However, the problem of inadequate investment in R&D, particularly R&D in the manufacturing sector, may be more acute in Canada than in other OECD countries. For example, manufacturing R&D is approximately 0.35 per cent of GNP in Canada and 1.6 per cent in the U.S. Much of the difference can be accounted for by the greater share of manufacturing output in GNP in the U.S., by the heavier defence research in the U.S., and by the heavier concentration of U.S. manufacturing in research-intensive industries (see Watson 1981). However, a significant difference remains. The average R&D-to-sales ratio of Canadian manufacturing is about 68 per cent of its U.S. counterpart (see Caves, Porter, and Spence 1980). Some of this difference may be attributed to underestimation of R&D in Canada relative to the U.S.: small firms, of which there is a greater proportion in Canada, do not report formal R&D expenses, since their R&D functions are likely to be a by-product of other activities (see Scherer 1980). Nevertheless, it seems clear that these figures are reasonably representative of the real situation.

Moreover, if R&D is critical to the prosperity and survival of high-tech industries, the low share of manufacturing output in Canada accounted for by these industries may be a result of the low R&D level, rather than its cause. Although these industries spend more on R&D as a percentage of sales than do most other Canadian manufacturing industries, their outlay is considerably lower than that of their counterpart industries in the U.S. This, some argue, may be the reason for their relatively low share of manufacturing output.

The policy implication of this R&D differential in high technology and manufacturing depends on its cause. Are there structural and policy elements in the Canadian economy that make the private returns to R&D unattractive relative to its social returns? Or does the low level of R&D reflect a low social return, which results from a lack of comparative advantage in R&D or an inability to appropriate its benefits to the nation? If the latter is the case, does this indicate that in the absence of heavy support, high-tech industries will not grow or even survive?

The answer to these questions depends critically on the importance of innovation for survival and prosperity in high-tech industries. In particular, it depends on whether there is a significant advantage in being first. Such an advantage may accrue from several sources: from learning-by-doing, which improves the economies of operation of incumbents relative to newcomers and possibly the efficiency of their R&D; from consumer acceptance and brand loyalty, which enable incumbents to protect themselves from competition; from development of patent rights, R&D capacity, and – what is perhaps more important – the ability to commercially exploit the results of innovation. The importance of such advantages of priority, which may be different in international and national markets, must be assessed in the light of theory and evidence. These advantages must also be weighed against the savings in R&D, marketing, and so on, that may be associated with being a free rider or a licensed imitator.

In the following chapters we shall attempt to shed some light on these questions. Because of the critical importance attached to R&D by the proponents of positive industrial policies, our analysis will concentrate on the question of R&D generally, rather than on R&D in high-tech industries alone. Since the rationale for government intervention depends critically on the relationship between R&D and growth, Chapter 3 examines the evidence on the effects of R&D on national growth, industry growth, and growth in the rate of technological diffusion. Chapter 4 discusses in detail the various advantages of priority and their policy implications.

3

R&D and growth

Essentially, three arguments are put forward by the proponents of further government encouragement of R&D in Canadian industry. First, it is argued that R&D is a major contributor to growth in general and to the growth of specific high-technology industries in particular. Second, firms that do undertake R&D are said to expand and prosper at the expense of those that do not, particularly in high-technology industries. Third, higher R&D expenditure is said to lead successively to greater receptiveness to technological advances, more rapid diffusion of new technology, and faster industrial growth.

As we indicated earlier, these arguments are not by themselves sufficient grounds for government support. If private returns to firms are high, that should be sufficient incentive for investment in R&D. If R&D is to justify government support, its social benefits must exceed its private benefits; that is, the effects of R&D on growth and welfare must exceed its effects on the profitability of individual investors. We shall return to this question, but first we shall attempt to evaluate the above arguments separately from the question of excess social benefits.

Owing to the paucity of Canadian research on the subject, we shall have to rely mostly on theoretical and empirical evidence relating to other countries – namely, the U.S. and the United Kingdom. Obviously, application of these results to the Canadian case must be made with care. As Berkowitz and Kotowitz (1982) point out, the position of a small, open economy is very different from that of a large economy, which may be treated as a closed system. Nonetheless, considerable insight can be garnered from this evidence, if it is interpreted carefully.

R&D AND NATIONAL GROWTH

Is there any evidence that the level of R&D expenditure within an individual country is a major determinant of that country's growth rate or the rate of growth of its factor productivity? While the evidence is hardly conclusive, it suggests that in fact R&D conducted within an individual country has little effect on productivity growth and may also have little effect on growth in general.

Production function studies for the U.S. that treat R&D activity as if it were an input into the productive system yield exceedingly variable and disappointing results. Although Denison (1962) estimated that one-twelfth of the annual per capita growth rate from 1929 to 1957 could be attributed to organized R&D – though technology growth in general accounts for a higher fraction – there is little evidence that the enormous postwar growth in R&D expenditure in the U.S. accelerated its growth rate during the 1960s and early 1970s. Moreover, while research intensity, as measured by the proportion of expenditure on R&D relative to GNP, is considerably higher in the U.S. and Britain than it is in Continental Europe or Japan, the U.S. and the UK had considerably lower rates of growth than did Continental Europe and Japan during the 1960s and 1970s.

If the effects on growth of R&D expenditure cannot be easily detected in large countries, which are much more likely to be self-sufficient in technological development, it seems unlikely that the effects of R&D expenditure on growth would be significant for small countries such as Canada.

Denison (1962) suggested that the lower overall effect of R&D expenditure on growth may be accounted for by the fact that most such expenditure is devoted to new product development, rather than to the improvement of productivity. As improvements in products are not properly accounted for in the national accounting of growth, the effects of such product developments will not be captured. This argument is not satisfactory: if the benefits from the development of new products remain in the country of development, they must appear in the form of higher corporation profits or wages, both of which are included in the national accounts.[6]

The evidence on specific industry or sectoral growth as a function of R&D is more favourable, although the direction of causality is far from established. In studies limited to a very few industries, Griliches (1964), Mansfield (1968), and Minasian (1962, 1969) found that R&D expenditure explained a significant portion of output growth by industry and yielded quite high, though exceedingly variable, industry rates of return. However, in a pooled time series analysis for the period 1959-76 for 28 industries in the U.S., Griliches and Lichtenberg (1982) found no significant effect of R&D industry expenditure on output, possibly because of their assumption of constant output elasticity across industries. In an earlier study using different data (Griliches 1980), such a relationship was established, but when the results were disaggregated by period the relationship between changes in R&D and total factor productivity almost vanished, perhaps suggesting a weakening of R&D productivity in recent years.

Cross-sectional studies that compare growth in different manufacturing industries and relate it to the research intensity of these industries yield much more positive findings. In particular, Freeman (1974) obtained high correlations between the level of research expenditure as a percentage of net output for seventeen industries in the UK in 1958 and the growth of output of these industries between 1935 and 1958. In view of the time period chosen, however, an inference of causality from R&D to growth does not seem justified. Somewhat stronger evidence of the same nature was offered by Leonard (1971), who found a strong correlation between R&D intensity and industry growth in the U.S. and carried out partial tests for the direction of causality. His results suggested that the direction is from R&D to growth, rather than the reverse.

The results of more recent studies by Griliches and Lichtenberg (1982) and Scherer (1982a,b) confirm and strengthen these findings. Interindustry differences in the growth of total factor productivity were found by Griliches and Lichtenberg to depend significantly on R&D intensity as measured by the R&D-to-sales ratio. In particular, privately financed R&D appears to exert a much stronger influence on productivity growth than government-financed R&D performed by industry, the effects of which are negligible. These relations are stronger during the 1970s than during the 1960s, in sharp contrast to the time series results. The coefficients on R&D in this study can be loosely interpreted as the gross excess social rate of return to R&D over its private return as a percentage of R&D investment, because the conventional inputs of labour and capital used in the calculation of total factor productivity already include R&D inputs. These estimates therefore imply an average of 5.6 per cent excess social rate of return to privately financed R&D investment undertaken during 1959-63, a figure that rises to 20.5 per cent for 1964-8 and 36.0 per cent for 1969-73.

Scherer's studies, which relate productivity growth during 1973-6 to 1974 industry R&D expenditure, reinforce some of these results and cast doubt on others. In general, R&D intensity is found to be significantly related to the growth of total factor productivity. However, this relationship is not confined to the industry that performs the R&D: indeed, the greater part of the effect occurs in the industry that *uses* the products produced by the industry investing in R&D, rather than in the investing industry itself. As Scherer points out, most industrial R&D (about 75 per cent) is product- rather than process-oriented. Moreover, most product R&D is performed in industries that produce industrial capital goods products (45 per cent) and industrial materials products (21 per cent), most of which are sold to other industrial users. Only a small fraction is invested in consumer product innovation.

The extent to which an innovation benefits the firm or industry that develops it, rather than the industries and consumers that use it, depends upon the ability of the originating industry to raise prices in line with quality improvement. The results cited above suggest that, on the whole, the forces of competition prevent firms from appropriating the gains that arise from their product innovations, which accrue instead to industries using the products or to consumers. In contrast, process R&D, whose results are usually used within the firm, leads to significant increases in productivity within the investing industry.

In general, the evidence for Canada suggests that R&D is not a major factor in explaining the relative growth of Canadian industries. Lithwick (1969) found no significant correlation between R&D expenditure per dollar of sales of different industries in 1955 and either the subsequent growth rate of industry output or the growth rate of factor productivity. While Lithwick's tests were relatively crude, a later, more extensive study by Globerman (1972) supports his results. For a variety of time periods and measures of industry growth (sales, assets, net income, etc.), Globerman found no significant association between research intensity and industry growth. Nor did he note any significant positive effect of research intensity on the growth of factor productivity. These results appear to be insensitive both to tests separating primary from secondary industries and to the introduction of such additional explanatory variables as concentration and the degree of foreign ownership. Moreover, the results of this study do not support the common view that foreign ownership retards either the performance of R&D or its effective utilization.

Globerman (1972) also tests a claim of the Special Committee on Science Policy (Senate of Canada 1970) regarding economies of scale in R&D. The Committee had argued that there is a minimum threshold of R&D expenditure per firm below which no significant results can be expected from the research effort, and that many Canadian industries fall below this threshold. The Committee suggested a threshold of an annual R&D budget of about $120,000 and at least five qualified scientists and engineers per firm. Globerman found that of the fourteen manufacturing industry groups only six fulfilled these conditions. There was no evidence that R&D expenditure in these industries had any effect on their factor productivity.

A more recent and elaborate study by Postner and Wessa (1983) supports some of these results. The study finds that R&D performed by a given industry has no significant relation on its own labour productivity growth. However, Postner and Wessa claim to have found a significant effect of Canadian R&D on labour productivity growth in Canadian manufacturing through R&D embodied in industry inputs. This evidence is similar to Scherer's (1982a, b), which we discussed earlier, and supports the proposition that innovators can seldom appropriate the full benefits of their innovations, which mostly accrue to downstream industries or to consumers. However, because the calculations carried out by Postner and Wessa do not account for R&D embodied in imports, its effect is attributed to Canadian R&D in import-competing products. Consequently the true marginal effect of Canadian R&D tends to be highly exaggerated. Moreover, the statistical results are contradictory: R&D performed by an industry appears to contribute significantly to the productivity growth of downstream industries; on the other hand, R&D contracted out by an industry contributes even more significantly to a reduction in productivity growth in downstream industries.

All of the studies cited suffer from many deficiencies in method and data, but they do indicate that there is little evidence that the level of R&D expenditure in a country has a decisive effect on its growth rate. While the evidence does suggest some relationship in the U.S. between specific industry growth and the intensity of R&D in that industry, the direction of causality in that relationship is far from established. It is possible, for example, that industries particularly receptive to innovation tend to grow more than other industries and also attract a greater amount of R&D. The evidence for Canada does not even point to an association between R&D and growth, let alone to R&D as a cause of growth.

The apparent weakness of the link between R&D in Canada and the pattern of industrial growth is not surprising. The rate of industrial growth depends not only on innovations generated within the country but also on the pool of innovations available to a given industry, wherever the innovations are generated. R&D in a small country such as Canada cannot possibly account for a major portion of world innovation; consequently most innovations adopted by domestic industry will originate outside the country. Rates of productivity growth in Canadian industry are, therefore, likely to be more affected by technological investment elsewhere than by research performed specifically in Canada, particularly because research intensity in Canada is low relative to that in the U.S. and other advanced countries.

Moreover, it can be argued that R&D activity in Canada is designed at least in part to implement or supplement foreign technology, where such technology is not easily adaptable to Canadian conditions. If this is the case, then R&D intensity in Canada may be *negatively* related to the flow of innovations that are available for Canadian use and that determine the rate of Canadian productivity growth. This possible negative relation may bias the results of Globerman's equations, eliminating the effect of local R&D on productivity growth (see also Caves, Porter, and Spence 1980). If this argument holds, it underscores the importance of the diffusion and implementation of innovations in the process of growth. While such diffusion and implementation is not independent of R&D, it is clearly different and its relation to R&D must be evaluated carefully.

The apparently weak effect of R&D on Canadian growth also points to the difficulties innovators have in appropriating benefits of their inventions and innovations. Again, these benefits can be only partly appropriated by the innovators (Scherer 1980), with the balance accruing to imitators, other industrial users of the improved products and technologies, and the consumers of the products generated by innovation. Even where patent protection is relatively effective in preventing unauthorized use, sufficient incentives must be given to users of the innovation, or to potential consumers of new products, to spread the benefits of such innovations far beyond the country of their origin. This diffusion of benefits is particularly important for a small, open economy such as Canada.

R&D AND FIRM GROWTH

The second argument in favour of increased R&D investment is that firms that undertake R&D grow at a faster rate than firms that do not. This argument is usually said to be particularly applicable to the technologically intensive industries, in which industrial growth is concentrated and in which the majority of major innovations originate. If this argument is correct, then low R&D by Canadian firms in these industries is bound to lead to a weakening of their position relative to firms in other countries and hence to a decrease in their competitiveness. As these are the industries that grow fastest, this development is certain to lead to a decrease in the rate of general industrial growth. Moreover, because some of the less research-intensive industries in which Canada has existing productive capacity – such as textiles and leather, automobiles, consumer durables, and metals – are becoming increasingly subject to competitive pressures from developing countries, Canada cannot easily make up for any deficiencies in the growth industries by expanding production in these traditional areas. Since the demand for the growth industries' products is likely to expand at a high rate, it is the export- and import-competing performances of the growth industries that must offset increased imports of the traditional products. The remedy proposed is to strengthen firms in growth industries by encouraging them to perform more R&D and thereby hold their own in export- and import-competition.

Canada's current export structure is concentrated in industries that spend relatively small amounts on R&D. Thus Daly and Globerman (1976) found that industries in which Canada has a comparative advantage (i.e., in which exports exceed imports) are relatively less technologically intensive then other industries in terms of the ratio of professional and technical employees to all employees. However, they found no indication of a relationship between relative competitive disadvantage and technological intensity: industries in which imports considerably exceed exports do not appear to be less technologically intensive than those in which the excess of imports is small.

In contrast, studies by Keesing (1967) and Baldwin (1971) found R&D has a significant effect on export performance in the U.S., where much export activity is concentrated in technologically intensive industries. Moreover, Caves, Porter, and Spence (1980) found R&D in the U.S. to be a significant factor in the share of industry output accounted for by multinationals in Canada. Significant R&D investment apparently gives U.S. firms an advantage in Canadian markets. Since Canadian production is frequently a substitute for imports (owing to tariff barriers), this finding reinforces the importance of R&D in the determination of U.S. comparative advantage.

A study of innovation in five Canadian industries undertaken by the Economic Council of Canada (De Melto, McMullen, and Wills 1980) showed that many of the products innovated by these industries were exported: significant innovation is thus associated with exports. However, these observations were restricted to a relatively small number of successful Canadian innovations, and it cannot be inferred from this evidence alone that R&D is important as a determinant of exports.

The evidence that relates R&D intensity to the success of firms is also far from conclusive. Caves, Porter, and Spence (1980) found that R&D intensity in Canada exerts a negative effect on industry and individual firm profits, particularly in industries dominated by Canadian firms. They conjectured that this effect appears because the R&D performed by these firms is mainly defensive, indicating vulnerability to foreign competition, and not because such R&D is intrinsically unprofitable.

However, the rents that foreign subsidiaries collect in Canada from R&D performed abroad contribute positively to reported excess profits.

There is more evidence about this question in the U.S. and the UK. There is no doubt that the returns to *successful* innovations are quite high, whether these returns are measured in terms of financial return to the companies or in terms of company growth (see Mansfield 1968, Mansfield et al. 1977, Smith and Creamer 1968, and Baily 1972). However, the relationship between R&D intensity and firm profitability, whether in general or within specific industries, is less clear. Griliches (1980) investigated the productivity of R&D at the firm level by estimating the output elasticity of a large number of U.S. companies that perform significant R&D. The results for the productivity of R&D within each firm were extremely variable and sensitive to the choice of assumptions. In any case, because the evidence was confined to firms that are very large relative to Canadian firms, the applicability of these results to the Canadian situation is questionable.

Of more interest is a study by Griliches and Mairesse (1982) that compared productivity growth by firms in France and the U.S. The authors estimated that the gross rate of return to firm R&D was about 25 per cent in both France and the U.S., but they found little evidence of differences between firms in the *same* industries. The lack of such evidence may reflect the greater homogeneity of firms within industries – or it may indicate that there is in fact no causal relationship between increased R&D and increased productivity, both of which may simply derive from increases in technological opportunities. The study makes the interesting point that French firms appear to be much more specialized in their R&D than their American counterparts. Almost two-thirds of the large French companies examined did not report any R&D investment at all, but those who did undertake R&D were more heavily committed to it than their U.S. counterparts and had a higher R&D-to-sales ratio. While the average R&D-to-sales ratio in France is lower than it is in the U.S., industry productivity is increasing at a faster rate in France than it is the U.S., in spite of the common rate of return to firms from R&D investments. This result may reflect, once again, the difficulty of appropriating the results of R&D to the country of origin.

Mansfield et al. (1977) reported on the private rate of return to R&D of a major industrial firm during the period 1960-72. The firm's estimated gross rate of return for relatively large innovations was 19 per cent; product R&D yielded a 15 per cent and process R&D a 22 per cent rate of return. However, the results for individual years and projects were extremely variable, ranging from –15 per cent to over 30 per cent. Mansfield et al. (1977) also reported a high variability in the probabilities of success: for three similar chemical firms, for example, the percentages of R&D expenditure that were economically successful in 1968-71 were 79, 54, and 39, respectively. The different proportions may reflect differences in efficiency.

Similar observations were made by Freeman (1974). Studies by the Federation of British Industries (1961, 1974) indicated positive but weak correlations between firm growth rates and overall R&D intensity, with a much stronger association at the extremes. Again, however, the paucity of evidence does not enable us to reach a clear conclusion. Such evidence as we do possess suggests that if Canadian firms in the technologically intensive industries perform little or no R&D, they are indeed likely to lose competitiveness and suffer a decline. However, should they perform at least a minimum of R&D, they will not necessarily be placed in an inferior position vis-à-vis their foreign competitors.

It is important to distinguish between innovation and imitation. Generally, much more R&D investment is necessary for the former than for the latter. The size and extent of the relevant market is also important. To compete internationally in major innovations, with a view to capturing significant market positions worldwide, would require enormous resources in relation to Canadian corporate size; Canadian firms would have to compete with enormous U.S., European, and multinational corporations. But maintaining a competitive position within the Canadian market or internationally, through limited product innovation designed to fill a narrow niche in differentiated product markets, may require much smaller R&D resources. Thus competition in innovation (like competition in general) is dictated by the degree of product differentiation and by the degree to which markets are segmented locationally, whether by transportation expenditure or by special product requirements. To the extent that Canadian firms restrict themselves to local and specialized international markets, they may be successful despite a low level of R&D in absolute terms (owing to their small size) or even low R&D intensity relative to other firms in the industry.

The recent Economic Council of Canada study alluded to earlier (De Melto, McMullen, and Wills 1980) illustrates some of these possibilities. About half of the 'innovations' reported in this study were imitations of innovations that were first introduced elsewhere in the world, with an average lag of about eight years. This proportion probably underestimates the true magnitude of imitative activity, since the sample was confined to major innovations by the responding firms and excluded run-of-the-mill technical utilization of existing knowledge. In spite of the long adaptation lag, these innovations were generally profitable. Half of the reported innovations were original to Canada, and some of these resulted in significant exports of the innovated products. But in general the product innovations involved very modest R&D costs (a median of $260,000) and relatively small sales (a median value in 1978 of less than $1 million) and export values (a median value in 1978 of less than $500,000). The innovating firms indicated that most product innovations, particularly those introduced by small firms (which constituted more than 50 per cent of the innovations in the sample) were designed to fit a specific market niche rather than compete in a broader market.

The evidence of Hollander (1965) and in particular that of Katz (1971) as cited by Freeman (1974), also supports this view. Katz's results, based on a comprehensive time series study of about 250 firms in Argentina, are of particular interest: they suggest that in a small country technical adaptation is more valuable for firm growth and success than R&D that aims at originality. This conclusion points out the danger of basing policy on the arbitrary distinction that is generally made between R&D activities and activities that involve the adaptation of acquired innovations.

Many Canadian firms that deal in high technology emphasize activities of the latter kind (Caves, Porter, and Spence 1980). In the electronics industry, for example, most firms are small; they either supply the domestic market or offer specialized services in the international market in the form of custom chip and system design, but do not compete in the production of hardware such as semiconductors, integrated circuits, mainframe computers, and consumer products (Choudhry, Cohen, and Saunders 1981). Caves, Porter, and Spence (1980) argue convincingly that this pattern reflects comparative advantage in a small, open economy in the presence of product differentiation, economies of scale, and the advantages of market proximity. More important than the relatively low transportation expenses associated with market proximity are the marketing advantages: because local firms can readily communicate with their customers and share their customers' cultural values, they are better able than more distant firms to tailor their products to local demand. Marketing advantages also facilitate successful product innovations. In the presence of a differential comparative advantage owing to factor abundance or historical causes, some specialization will take place in products for which the advantage of economies of scale is sufficient to offset locational advantage. In this scenario, countries possessing a comparative advantage in different product lines will export to each other.

The role of R&D in this context is to facilitate product innovation in order to ensure competitiveness, particularly the competitiveness of firms that sell specialized products filling specific niches in export markets. Such R&D must be more original than the R&D in industries that are protected by strong locational advantages; for the latter, imitative R&D may be sufficient. Tariffs, like increases in transportation costs, induce greater local advantage and thus facilitate local production of product varieties in spite of the cost disadvantages of small-scale production.

However, the empirical and theoretical evidence does not support a conclusion that firm success is universally dependent on R&D intensity, even in technologically intensive industries. While a minimum R&D level is probably required for survival and expansion in such industries, there is no evidence that higher levels of R&D will necessarily be profitable. The level of R&D required appears to be a function of the relevant market structure and product characteristics. To the extent that Canadian firms are restricted to filling a narrow locational niche in differentiated product markets, imitative innovation that requires only low R&D investment appears to be successful.

However, there are significant exceptions to this pattern. Canadian firms in the urban transportation, aerospace, and nuclear industries compete vigorously in international markets; in the telecommunication industry, whose largest firm, Northern Telecom, accounts for a major share of industry shipments, Canada is a world leader. It has been argued that increased government support of original R&D is necessary both to sustain the viability of firms in these successful industries and to increase the incidence of similar endeavours. But before we evaluate arguments for government support of R&D, it remains to examine the third argument in favour of increased R&D – namely, the argument that the relatively slow rate of diffusion of innovations in Canada, the result in part of a lack of technical information owing to low R&D expenditure, causes Canadian industry to fall farther and farther behind its competitors.

R&D AND TECHNOLOGICAL DIFFUSION

While there is ample evidence that Canada does lag behind the U.S. and possibly Europe in the diffusion of innovations, it does not follow that such lags will cause Canada to fall farther and farther behind its competitors. Such lags may help to explain the lower *level* of Canadian productivity relative to U.S. productivity, but unless the *rate* of diffusion is falling over time, Canadian industry will not fall increasingly far behind. By the same token, a faster rate of diffusion of innovations would clearly raise the level of productivity in Canada relative to the level in the U.S., but unless the rate continued to increase it would not cause a continuous improvement in the rate of productivity growth relative to the U.S. rate.

However, to the extent that the rate of technological progress is accelerating in any particular industry, failure to adopt new technology relatively quickly may cause Canadian producers to fall increasingly behind their foreign competitors in that industry. It has been argued that this is the case in technology-intensive growth industries, and that therefore the share of Canadian producers in these industries is bound to fall in the absence of local protection.

Unfortunately, evidence about the diffusion of innovations in Canada is extremely sketchy. While there is evidence that both interfirm and intrafirm diffusion rates in Canada fall short of those in the U.S. and Europe, the reason for this lag has not been established empirically. What evidence we do possess is suggestive at best, and we do not have any evidence about the behaviour of such lags over time. That is, we simply do not know whether the rate of diffusion has been accelerating or decelerating in Canada relative to other countries. Moreover, because the evidence is confined to a small number of case studies, and does not cover high-technology industries, we cannot evaluate empirically the hypothesis that Canadian firms are falling behind their competitors in these industries.

There are five case studies of the diffusion of specific innovations in Canada relative to the U.S. or Europe. Hufbauer (1966) found that production of new synthetic materials first took place in Canada about fourteen years, on the average, after production had been initiated elsewhere. Daly and Globerman (1976) found that the speed of interfirm diffusion of numerical control (n.c.) machine tools was considerably slower in Canada than in the U.S. While the very short time periods covered by the data limit the validity of the authors' econometric conclusions, their qualitative conclusion that the Canadian rates of adoption fell significantly short of those in the U.S. is clearly valid. During the period from 1961 to 1968, for example, the percentage of U.S. firms using numerical control machine tools rose from 1 per cent to about 20 per cent, while in Canada the corresponding figures were 1 per cent and 10 per cent. Daly and Globerman obtained similar results for the use of special presses in papermaking, showing slower interfirm and intrafirm rates of diffusion in Canada relative to most European countries. Finally, Globerman's study of tufting equipment in carpet-making (1973) repeats the pattern. Globerman found a three-year lag between the initial introduction of tufted carpets in the U.S. and their introduction in Canada, and a similar lag in further intrafirm and interfirm speed of adoption.

The reasons for these diffusion lags are not well established. In particular, their connection with R&D activity within the firm is not clear. Recent studies by the Economic Council of Canada (De Melto, McMullen, and Wills 1980, McMullen 1982) suggest that some internally conducted R&D is necessary for the adoption of major foreign innovations, even in the case of foreign subsidiaries that adapt technology from their parents. However, this R&D consists mostly of startup expenses for process innovations and marketing expenses for product innovations; it includes only a small research component.

The speed of adoption of foreign technology depends, of course, on the competitive environment. It is also likely to be related negatively to the cost of the technology and positively to the size of the market the technology is expected to serve. Because the benefits of adoption are proportional to the size of the firm, large firms are likely to adopt new process innovations earlier than small firms. However, because new products compete with existing products, established firms are less likely to adopt new products first.[7] Early adoption of product innovations is likely to come from outsiders or from the smaller fringe firms in an industry, for whom this practice is a major avenue of expansion.

Firm size may be related to early adoption not only for these structural reasons, but also for purely statistical reasons. If the unit of adoption is a plant rather than a firm, and if adoption by an individual plant is purely random, it is clear that the probability of adopting an innovation is greater for a large (multiplant) firm than for a small firm. A second statistical reason for the earlier adoption of innovation by large firms is that adoption may require new capital equipment, either for expansion or to replace existing equipment, and large firms are more likely than small firms to have equipment in need of replacement at any specific time. Therefore, a larger firm is more likely than a small firm to be in a position to adopt an innovation quickly.

These statistical reasons do not imply that innovations will be adopted more quickly in a concentrated industry than in a non-concentrated industry; however, if large firms do adopt innovations more quickly than small firms, then the more concentrated is a given industry, the earlier it is likely to adopt innovations, because concentration implies an increase in the average size of firms in the industry. On the other hand, rivalry should retard first adoption as concentration increases.

The empirical evidence, scanty as it is, provides some support for these propositions. Thus both Mansfield (1968) and Romeo (1975) found that larger size leads to earlier adoption. However, neither Mansfield nor Romeo was able to determine whether the effects of size are greater or smaller than the effects that would be predicted by chance alone. Consequently, the structural effects of size have not been tested directly. An indirect test is the effect of projected profitability, reported through questionnaires completed by the firms, on the rate of early adoption. Because projected profitability is likely to be affected by firm size, significant acceleration of adoption owing to increased projected profitability would indicate some support for our hypothesis. While some such support does exist, it is not very significant. The effects of rivalry on early adoption have not been directly tested.

Early adoption of an innovation by a firm does not guarantee that the innovation will be fully utilized by all of the plants of the firm. The speed at which the industry as a whole utilizes an innovation depends not only on the rate of adoption by individual firms but also on the rate of diffusion of the innovation within each firm. Here, in fact, the evidence suggests not only that the rate of diffusion is slow in large firms after the date of first adoption, but also that late adopters have faster rates of diffusion than early ones.

Daly and Globerman (1976) compared the diffusion of three innovations in Canada with their diffusion in the U.S. and Europe. They attribute the low rate of initial adoption of numerical control machines by the Canadian tool and die industry, relative to the rate in the U.S., to the small size of the average Canadian company relative to its U.S. counterpart. However, they too are unable to determine whether this difference in rates arises from the random effects of size or from the effects of increased profitability. In discussing the introduction of a process innovation in the paper industry and a product innovation in the carpet-making industry, they attribute the significant delay in the introduction and diffusion of these innovations in Canada relative to other countries to the lack of competition in these Canadian industries. While their evidence is mostly qualitative rather than quantitative, it is consistent with the theory stated above and with Romeo's empirical results. On the whole, there is little evidence in any of these studies to suggest that R&D is important in the adoption process.

In summary, the causal connection between the amount of R&D performed in Canada and the degree of competitiveness and profitability of Canadian industry in general, and of high-technology industry in particular, has not been convincingly established. Clearly, many Canadian industries perform a considerable amount of R&D profitably, but it is not clear whether, at the margin, increased R&D would be highly productive. Even if the social benefits of growth in these industries exceed the private benefits – owing, for instance, to market imperfections that inhibit the private profitability of expansion in high-technology industries – it is far from clear that increased R&D is the best way to stimulate such growth. As this review of the evidence should suffice to show, arguments to the contrary must be based on faith rather than on science.

4

The advantages of priority

There is one important exception to the conclusion advanced at the end of the preceding chapter. A case can be made for increased R&D in the pursuit of the major product and process innovations that Canada will need if it is to establish a significant competitive position in international markets for high-technology products in industries in which technical progress is extremely rapid (such as semiconductors, computers, communications, instruments, aerospace, and nuclear technology) and in which Canadian corporations already have some market presence and competence. Two paths to success seem open: small-scale innovation to establish a niche in a specialized branch of international industry, and large-scale competition for industry leadership in a major area.

Both approaches have attracted large and increasing amounts of support from most OECD governments. In addition to general tax concessions and subsidies to R&D, such industries have received direct government sponsorship and entrepreneurial effort in the form of promotion of corporate mergers and direct ownership of corporations (France and the UK), government-sponsored co-operative industry research efforts (Japan), government contracts for sponsored research (the U.S.), and preferential procurement policies (all countries). Most of this support is directed to major innovations, which will, the sponsors hope, lead to a dominant or at least a competitive position in the international market for the relevant firm or industry.

The rationale for such programs (aside from national prestige) depends upon the benefits to be garnered from such a market position. Because there are believed to be significant static and dynamic economies of scale in these industries, the number of successful firms in each product line is likely to be small worldwide (or at least within the relevant markets), a circumstance that will facilitate co-ordination and, in effect, lead to monopoly profits or persistent above-average returns. Sponsors may also expect that these firms will create externalities in the form of spinoffs to local suppliers and increased wages, given the locational advantages of the local industries that will supply the dominant firm or use its products. The achievement of such a dominant position, it is often argued, may require priority in innovation. The advantages of such priority may arise from patent protection, from 'learning by doing', from consumer acceptance and brand loyalty, or from strategic behaviour intended to retard or foreclose entry by latecomers without losing all of the rents that accrue to dominance. While all of these advantages may accrue to a firm with priority in innovation, there is no general agreement about their quantitative importance as a source of monopoly rents for a firm (or its sponsoring country). Nevertheless, in view of the apparent importance attached to this line of thought by many advocates of a high-tech industrial policy, it is worth evaluating each of these possible advantages of 'being first' more carefully.

PATENT PROTECTION

Patent protection may provide significant advantages to innovators, since it confers upon them exclusive rights to the use of the innovation over a long period (currently seventeen years in most countries). However, patent protection is far from absolute. Mansfield, Schwartz, and Wagner (1981) found for a sample of product innovations in chemicals, electronics, machinery, and drugs that imitation costs were thought to increase due to patent protection by averages of 11 per cent for patented innovations and 6 per cent for unpatented innovations. This is not a very significant degree of protection, and imitators can usually (though not always) get around patents within a fairly short time. In fact, the disclosure requirements for patent award may make the imitator's task easier. Thus many innovators do not take out patents on their innovations, relying instead on secrecy.[8]

LEARNING BY DOING

The experience acquired as a result of the development of new products ('learning by doing') confers priority advantages in several ways. For one thing, costs of production usually drop as experience is accumulated. There is significant evidence of the existence of such cost reductions in various industries. According to Spence (1981), for example, aircraft production cost per unit falls by 20 per cent for every doubling of cumulative output; similar results are reported by Choudhry, Cohen, and Saunders (1981) for an electronics product in Canada.

However, not enough is known about the precise shape of the learning curve to gauge the importance of learning by doing as a barrier to entry for imitators. If the effects are temporary – that is, if learning economies are exhausted with small production – learning by doing is not an effective barrier, since an imitator can gain such economies rapidly. Entrants may also acquire this knowledge by hiring away staff. However, the most important weakness of learning by doing as a barrier to entry is the circumstance that the industries in which learning is most important (such as the semiconductor industry) are subject to very rapid technical change, which makes acquired knowledge obsolete. Consequently, newcomers may not be at much of a disadvantage at all. In fact, to the extent that capital equipment is durable, priority may even be undesirable, since the first producers are stuck with aging capital equipment while newcomers can apply the latest technology.

Learning by doing may also confer significant advantages on innovators by increasing the efficiency of their R&D. Experience in production facilitates the development of new ideas. Such advantages are likely to occur mainly in process innovation (innovation directed at improving the production processes for existing products). This aspect of learning by doing was stressed by Mansfield et al. (1977), but there is little empirical evidence on the question. Scherer (1980) argues that such learning is transferable across related products. The effect of this transferability on the advantage of priority is unclear. In rapidly changing industries, early producers will maintain their advantage over rivals even when products and processes are changing rapidly. On the other hand, the transferability of knowledge from one industry and product to another also increases the number of potential competitors in related industries.

The advantage to early innovators also depends on the degree to which they can protect their knowledge from competitors. Many of the elements of experience can be internalized within the firm, but others cannot. Much of the value of information is embodied in key personnel or in products. As noted above, key personnel can be bought off by competitors, though long-term contracts may mitigate this problem. In the electronics industry and high technology generally, competition is frequently instituted by departing key personnel, who establish their own firms.

Mansfield, Schwartz, and Wagner (1981) documented imitation costs and time for a large number of product innovations. The average ratio of imitation costs as a proportion of innovation costs was about 0.65, and the ratio of the time required for imitation as a fraction of the time required for innovation was 0.7; both ratios were subject to a great deal of variability. An important factor in *reducing* imitation costs was the fraction of R&D accounted for by research: product imitators cannot easily avoid developmental and marketing expenses, but the product itself reveals much of the conceptual information resulting from research. Process innovations are probably more difficult to copy, so that learning by doing, which is likely to be more important for process innovations in any case, is also more likely to confer advantages on priority in these innovations.

BRAND NAMES

The importance of consumer acceptance and brand loyalty in conferring priority advantages has been stressed by Kotowitz and Mathewson (1978), Comanor and Wilson (1974), and others. The basic rationale is that risk aversion by consumers, possibly reinforced by advertising, causes consumers to value known products and to avoid experimenting with new products. This factor is particularly important where the consequences of a mistake may be serious in terms of product failure or relative expense and where information on quality is difficult to obtain. These elements are likely to be present in many consumer goods markets, particularly in markets for products that involve health and safety, such as drugs, and in markets for durable goods where outlays are large relative to consumer income and durability and maintenance expenses are hard to judge.

This argument is confirmed by an empirical study by Buzzell and Farris (1977), who found that relative to early (but not first) competitors, pioneering brands in consumer goods industries had a marketing cost advantage of 1.45 per cent of sales, while latecomers had a cost disadvantage of about 2.1 per cent. Similarly, Bond and Lean (1977) found that pioneering brands in two pharmaceutical products groups had a very large advantage – one that persisted for more than twenty years.

While consumer product R&D constitutes only a small fraction of total R&D, this pioneering brand advantage is also likely to be important in many capital goods industries, such as the nuclear generation and transportation equipment industries. There is considerable evidence that familiarity with other technology and the record of acceptance by others exert a powerful effect on buyers of nuclear generators and thus, for example, constitute a major barrier to the acceptance of CANDU reactors abroad. Similarly, demonstration of effective operation in commercial use is considered essential in the marketing of transportation equipment (Choudhry, Cohen, and Saunders 1981).

ENTRY DETERRENCE

The advantages of firms that are dominant in a market can be further reinforced by conscious defensive strategies to inhibit entry. A large volume of recent theoretical literature has analysed strategic entry deterrence policies. The essence of the argument is that strategic investments by dominant firms can inhibit entry. Such investments are costly, but they may put potential competitors at a disadvantage sufficient to exclude their entry or to keep it on a small scale. They may thus be justified by the avoidance of the rent losses that would result from entry.

The key element in most such models is a credible and binding commitment made by the incumbent before any rival enters the field to respond to entry with policies detrimental to such a rival (Schelling 1962). For example, a credible threat of predatory pricing will inhibit entry. However, the conditions under which such a threat is credible are extremely limited. Rivals know that predatory pricing is detrimental to the incumbent as well as to the entrant. Once entry has occurred there is no gain to the incumbent from following such a policy. To be credible, threats of actions that will damage entrants must be in the *post-entry* interest of the incumbent. Irreversible investments must be made to ensure that rational post-entry behaviour by the incumbent will be costly for entrants.

Most of the literature has concentrated on investment in physical capital as an entry-deterring instrument (e.g., Spence 1977, Dixit 1979, 1980, and Eaton and Lipsey 1981). However, Schmalensee (1982) and Gilbert (1982) demonstrated that the conditions under which such investment policies are likely to be significantly profitable are rare. Other weapons that have been suggested include advertising (Comanor and Wilson 1974, Schmalensee 1982, and Kotowitz and Mathewson 1978), locational decisions in geographical or product space (Salop 1979, Eaton and Lipsey 1979), investment in learning (Spence 1981), and investment in R&D (Gilbert and Newberry 1982).

We shall illustrate the use of R&D as an instrument to deter entry. Consider first a monopolistic industry that is subject to potential entry (Kotowitz and Mathewson 1978, Salop 1979). The monopoly is able to keep potential entrants from entering the industry under current technological conditions because potential entrants cannot enter with positive profits. The monopoly, however, is able to maintain a level of excess profits (monopoly rents). The monopoly may owe its advantage to economies of scale, to prior position, to lower costs owing to superior knowledge or the ownership of patents, or to the effectiveness of its advertising as a barrier to entry. Let the monopoly's profits in the initial period be P_0 and let its advantage over its potentially most efficient rival be C, where C is the level of cost savings per unit of output that the potential entrant requires in order to successfully enter the industry. That is, if the potential entrant is successful in reducing his prospective costs by C per unit he will be able to enter the industry without losing money.

Any innovation that yields cost savings of less than C is worthless to the rival, since it does not enable him to enter the industry. While the rival may be able to sell such an innovation to the incumbent monopolist, the price he obtains from the incumbent is likely to be exceedingly small, since there is no alternative use for the innovation. Consequently, if C is very large, potential rivals will not invest in R&D and will leave the field to the incumbent monopolist. However, if C is attainable with a reasonable amount of R&D effort, investment by potential entrants may be justified. Assume, for example, that an innovation that will reduce average costs by $C' > C$ is feasible with an investment in R&D of R. Such an innovation will enable the competitor to enter the industry with positive profits. The level of such profits, designated by P_2, depends on the nature of competition in the post-entry period. Because the incumbent knows that, given the innovation, he will be unable to exclude his rival from the market, he may choose to form a cartel with the rival, maximizing joint profits and distributing the resulting profit in some fashion between them. However, a more likely outcome is one that falls short of maximization of joint profits, since antitrust laws, difficulties of enforcement of cartel agreements, and bargaining difficulties are likely to prevent the cartel result. While the exact outcome thus depends on the nature of the competition in the post-entry period, the sum of profits of the two companies in the post-entry period will fall short of the potential profit of the monopolist if he had use of the innovation at no cost. If this potential profit is P and the post-entry profits of the monopolist are P_1, then $P_1 + P_2 < P$.

Entry need not take place, however, since the monopolist has the option of purchasing the patent from the potential rival and hence, in effect, bribing him to not enter. When is this option feasible and desirable?

The maximum price that the monopolist would be willing to pay for the patent is equal to $P - P_1$, since any price below this would leave him in a better position than he would be in if the rival entered. By the same token, the rival would never accept less than P_2, for otherwise he would be better off if he entered. However, as P is greater than $P_1 + P_2$, any price between these two extremes would leave both firms better off if the patent were purchased than they would be if no purchase occurred and the rival entered.

Consider now the value of the innovation to the two firms in question. Value to the entrant is simply equal to the price that he can obtain from the monopolist. As we have seen, this price can be anywhere between P_2 and $P-P_1$. The value of the innovation to the monopolist is the same, since it would save him the payment required to bribe the potential rival to stay out of the market. If there are several potential rivals, competition among them will induce them to invest in R&D until the expected value of successfully innovating and being bribed to stay out is just equal to their investment. For all of them together, R will equal the innovation price. If the monopolist wishes to prevent entry, he should therefore invest at least R in order to pre-empt successful entry. The knowledge that the existing monopolist invests R in R&D will be enough to deter potential rivals from such investment, since their chances of successful innovation prior to the monopoly will fall and therefore the expected value of the innovation will fall short of the investment.

In order to evaluate whether the threat of potential entry through innovation forces the monopolist to increase his investment in R&D, we must evaluate his incentive to invest in R&D in the absence of such a threat. The gross value of an innovation that reduces the monopolist's costs by C' per unit of output is $P-P_0$. This value clearly falls short of the maximum payment for the rival's innovation, namely $P-P_1$. It may, however, exceed P_2, which is the minimum payment to the rival for the patent. But note that even if the monopoly expects to pay only P_2 for the use of the rival's patent, and $P-P_0$ exceeds P_2, the threat of entry may affect R&D expenditure because, in order to pre-empt entry, the monopolist must invest at least P_2. If the threat does not exist, however, he will have to invest only up to the point at which $P-P_0-R$ is maximized, which may involve a smaller investment. In any case, it is clear that as C' rises with any given volume of investment the monopolist must increase his R&D expenditure in order to pre-empt innovation by outsiders. Moreover, as the monopolist's advantage vis-à-vis rivals (C) falls, the potential effects of the rivals' innovation are greater – that is, the greater will be the rivals' effect on the monopolist's R&D expenditure for the purpose of pre-empting such entry. The greater is the threat of potential entry by way of innovation, whether because of low entry barriers or because of ease of innovation, the greater will be the investment in R&D that a monopolist must undertake in order to protect his position.

There remains the important question of whether the monopolist is obliged to actually undertake such R&D, or whether the mere threat of doing so is sufficient to deter rivals, who know that the monopolist is able to pre-empt them should they try to engage in competitive R&D. It has been shown by Kotowitz and Mathewson (1978) that the threat of action is effective in deterring entry, if the threat can be executed without a time lag. Thus the threat of price reduction is an effective deterrent under certain circumstances because price reductions can be instantaneously executed. However, Kotowitz and Mathewson have shown that this rationale does not hold in the case of advertising because of the significant time lags involved in instituting advertising campaigns. The same conclusion holds *a fortiori* for R&D because the time lag between the inception of a research project and its successful termination is not only long but variable, so that it is not possible to forecast with any certainty when a research project will be successfully concluded or, indeed, whether it will be successful at all. A monopolist may thus fail to obtain priority in innovation relative to a competitor who has even a modest head start.

More important, it is exceedingly difficult to ascertain whether relevant R&D is being carried out by potential rivals. Indeed, since the identity of potential rivals is not always obvious, the task of identifying competitive R&D projects elsewhere may be impossible. The first intimation that such research is being conducted by potential rivals may be patent applications for related innovations, by which time it is probably too late to pre-empt the innovation. Conditions are probably more favourable for identification of potential competitive R&D where industries are well defined, so that the identity of potential rivals is well established (industrial spying may be effective in such cases). The use or threatened use of R&D to deter entry is most likely to succeed in the case of a dominant firm with smaller rivals on the fringes of the industry. Expansion of such rivals can only take place if one of them acquires a significant competitive advantage. The threat of innovation pre-emption may be sufficient in these circumstances to prevent excessive investment by the rivals. However, even in this case, the probability of detecting competitive research efforts may be so low as to nullify the power of a mere threat.

The logic of the preceding discussion applies equally well to oligopolistic market structures, for while price competition and even advertising competition may be prevented by explicit or tacit agreement it is almost impossible to control innovation competition. The situation is much more complex, however, where imitation is possible – where, for example, innovations cannot be effectively protected by patents, the benefits of priority are not clear. The possibility of imitation clearly reduces the gain from being first and decreases the loss from being second or third in innovation.

The analysis of product innovations is not fundamentally different. However, because the benefits of innovation or imitation depend on ultimate market shares, there is no *a priori* necessary relation between prior market shares and the benefits from innovation or imitation. Product innovations, which involve the development of substitutes for the products of the monopoly, are of benefit to rivals, but are of no potential benefit to the monopoly, except in that they possibly pre-empt rivals. Benefits from product innovations are therefore valuable to rivals, but not valuable to a protected monopoly – unlike benefits from process innovation, which are more valuable to the monopoly than to a rival.

Consider, again, the model of potential entry developed for the patentable innovation. In the product innovation case there are two significant differences. First, because of antitrust restrictions, the monopolist's ability to deter a rival from entering by purchasing his patent may be more limited, particularly when product innovation does not easily lend itself to patenting. In this case, a newcomer can benefit from product innovation only by way of actual entry. His profit is therefore limited to P_2, whereas in the case of process innovation he might be able to obtain more than P_2 in exchange for his patent. Second, the monopolist has an alternative to pre-emptive innovation as a means of preventing or at least minimizing the damage from entry by rivals: he can imitate the rivals' product. This alternative is thus analogous to the option of defensive advertising available to the monopolist in the Kotowitz and Mathewson model (1978). The effectiveness of imitation depends on the speed at which the rival can penetrate the market, relative to the speed at which imitation can take place, and on the effectiveness of the imitation itself. To the extent that effective imitation is feasible within a relatively short period, the mere threat of it is enough to reduce the profitability of offensive product innovation by potential newcomers. The possibility of effective imitation therefore reduces the required expenditure for pre-emptive innovation by potential newcomers and for pre-emptive innovation by the monopolist.

Finally, monopolists are less likely to pre-empt product innovations than process innovations because process innovations that reduce costs by the same amount are perfect substitutes for each other. It is not necessary for the monopolist to duplicate the specific process innovation contemplated by a rival. It is only necessary for him to invest in *some* process innovation that will reduce costs to the same extent. This is not necessarily the case for product innovations. Because of the diversity of tastes, the improvement of some characteristics of a product is not necessarily a good substitute for the improvement of other characteristics. Unless the characteristics at which a product innovation aims are well known, it is very difficult to pre-empt it. Dominant firms thus seem likely to be leaders in process innovation but followers in product innovation.

PRIORITY AND PROFITS

The analysis in this chapter of the advantages of priority suggests that patent protection and marketing advantage tend to lead to significant advantages for some innovations, but that the advantages of learning economies are somewhat less certain and are more likely to occur in process innovation at the stage in the product cycle when the rate of product innovation has slowed down. Firms that have successfully established themselves by this stage are likely to make supranormal profits, which appropriate defensive strategies can safeguard against actual and potential competitors.

Thus advantages do indeed seem likely to accrue to successful innovators. These advantages do not, however, necessarily fall to the first to innovate in the early stages of product development, when technological progress is extremely rapid and leadership is not easily maintained. Excess profits may well be earned by early innovators, but these profits may prove transitory as further product innovations and imitation erode their leadership position. Indeed, the best prospects for excess profits seem likely to accrue to firms that maintain leadership during the later stages of the product cycle, when the rate of product innovation has tapered off.

Whether economies of scale (static or dynamic) or other priority advantages are large enough to maintain a number of firms that is small enough to ensure excess profits depends on the specific industry. There are probably only a small number of industries in which a few firms dominate the industry worldwide; domination of an industry by a few firms is more likely to occur within limited protected markets such as North America or the EEC. However, even when the number of firms is small there is no necessary presumption of excess profits. Two industries that are heavily subsidized and that involve very small numbers – nuclear reactors and aircraft – show extremely fierce competition among a small number of firms (countries), with relatively low levels of profit.

Nevertheless the typical pattern of product cycle development does suggest the possibility of excess profits to firms that are successful in establishing a significant market presence first, before imitators are able to get in. The length of such leadership periods may be very variable, however. Hi-fi, TV, and video recorders provide examples of very short domination periods, while large computers, copiers, and film illustrate long-period domination. Uncertainty about the outcome of R&D (or other) competition is great.

Moreover, the existence of *ex post* excess profits for some companies, whether throughout the product cycle or just during its latter stages, does not necessarily imply *ex ante* profitability for R&D investment, since the potential for such excess profits will induce firms to invest heavily in R&D. Therefore, unless there are significant barriers to entry into the innovation race, the existence of such future excess profits may lead to excessive competition in the early stages. While the winners may have excess profit, there is no way to guarantee that, on average, resources will not be dissipated by the losers, so that on average there are no rents. Because competitors recognize this possibility, they may be reluctant to invest the large sums necessary in view of the significant risks involved and the low prior expectation of profits when the probabilities of success are evaluated realistically. Firms that do enter these races usually do so because they possess some other advantages that give them a better chance at winning, such as a strong base in a related industry, specialized knowledge, or patents.

In the absence of government support, Canadian firms may be at a disadvantage in entering industries such as those discussed here. Owing to the small size of the Canadian market, firms tend to be relatively small and to lack the financial, technical, and marketing resources necessary for success. Moreover, because many foreign firms are heavily supported by their governments, the expected private rate of return to Canadian innovators is likely to be very low; consequently even firms that might possess some advantages in such competition will be reluctant to enter the race, unless they are supported by the government. However, unless government support significantly increases the chances of winning, such support seems unlikely to yield a positive long-term social return – unless, of course, subsidization of the industries in question is warranted in any case for reasons of market imperfection.

5
Summary and policy conclusions

The arguments put forward by proponents of increased government support for R&D in Canada have now been critically examined and their theoretical and empirical validity found questionable. The causal connection between R&D performed in Canada and the growth of the Canadian economy in general has not been empirically established. The effects of R&D on the relative overall growth or productivity growth of Canadian industries appear to be small. While the evidence about possible effects of R&D on industry growth is somewhat stronger for the United States, it is still far from conclusive.

These results arise principally from the extreme difficulty of appropriating the benefits of R&D to the industry and country of innovation, let alone to the innovator. Neither patent protection and secrecy nor the advantages arising from priority in innovation may be sufficient to prevent imitation, so that many of the benefits from innovation accrue to consumers or imitators. For this reason, firms that do only a moderate amount of R&D, mostly of a defensive-imitative nature, appear to survive and prosper even in technological growth industries. We have found no significant evidence that the rate of diffusion of foreign innovations depends heavily on locally performed R&D.

The causal connection between R&D performed in Canada and the degree of competitiveness and profitability of Canadian industry, either in general or in high-technology industries in particular, has thus not been conclusively established. A considerable amount of R&D is clearly performed profitably in many Canadian industries, but it is not clear whether, at the margin, increases in R&D expenditures would be highly productive. The general case for increased government support of R&D must therefore rest on the discrepancy between the private benefits to R&D investors and the social benefits to Canadians of externalities conferred by the investors on their fellow Canadians as a result of the public goods characteristic of innovations.

The main possible exception to these conclusions is the case of major product or process innovations that are necessary to the establishment of a significant competitive position in international markets for high-technology products. In addition to its role in securing the potential excess of social over private benefits from such innovations, the government may have a role to play in enhancing the competitive position of Canadian innovators and improving their ability to appropriate to themselves the benefits arising from the innovations.

Some observers have argued that there are significant static and dynamic economies of scale in high-technology industries, which limit the number of successful firms in each product line and therefore result in high concentration and excess profits. It has also been argued that priority in innovation, which may require extensive R&D expenditure, is necessary to the achievement of significant market presence in such industries, because such priority confers advantages that are difficult for imitators to overcome.

The extensive examination of the advantages of priority in the present study supports some but not all of these arguments. Patent protection, though limited in scope and in its ability to prevent imitation, may nevertheless result in significant advantages for innovators. Similarly, priority in marketing new products may confer significant advantages in consumer-good and in some producer-good industries. The advantages of 'learning by doing', however, are less certain and are more likely to occur in process innovation at the stage in the product cycle when the rate of innovation has slowed down. Consequently, firms that have successfully established themselves by this stage are likely to make supranormal profits, which appropriate defensive strategies can safeguard against actual and potential competitors. Thus the advantages that accrue to successful innovators do not generally go to the firms that innovate at the early stages of product development, but rather to the firms that attain leadership in the later stages of the product cycle, when the rate of product innovation tapers off.

Moreover, the existence of excess profits *ex post* for successful innovators will generate competition for these profits, so that unless there are significant barriers to entry into the innovation race, *ex ante* profits for potential innovators are unlikely to be above average. Given foreign governments' support for such ventures and the high risk associated with them, Canadian firms seem unlikely to invest in such R&D unless supported by the government.

The implications for government policy in this area are twofold. First, to be effective, government intervention must improve the probability that Canadian firms will be among the winners. Second, the profit position of Canadian winners must be enhanced through measures that enable them to appropriate more of the benefits of innovation. Policies that attain these goals will improve the expected profitability of R&D investment aimed at major innovations and hence will generate the required investment. However, because of the low marginal expected profitability of such investment, it must be stressed that government subsidies or other financial support, unless accompanied by measures that improve the inherent profitability of the investment, are unlikely to be productive and must be justified on the general grounds of excess social benefits.

Thus in order to evaluate the desirability – and determine the desirable form – of government support for R&D in general and for R&D in high-technology industries in particular, we must first determine to what extent and under what circumstances marginal social benefits from R&D exceed private benefits in the Canadian context.

SOCIAL VERSUS PRIVATE BENEFITS FROM R&D

The excess of social benefits to Canada over private benefits to investors arises mainly from externalities conferred on fellow Canadians by R&D investors. Such externalities arise because of the public goods characteristics of innovations, which prevent the innovators from appropriating the full benefits attributable to the innovation, and because of the innovators' inability to discriminate perfectly among users of the innovation, whether consumers or complementary factors of production.

Excess social (over private) benefits are therefore likely to be shared by consumers or downstream producers in the form of lower prices or improved quality, either because of competition from imitators or because the innovator's inability to price discriminate causes him to reduce the effective price per unit quality even when he has a monopoly on the innovation.[9] Complementary factors of production may also benefit: for example, to the extent that labour productivity is improved by innovation, wages in the relevant industries may rise. However, since competing factors of production may be displaced by innovation, the *net* benefits to other factors may be small or even negative.

There is very little Canadian empirical evidence on the question of social versus private returns. Analysis must therefore rely once again on theoretical arguments and on evidence from other countries – mainly the

U.S. – which must again be interpreted with care because of the difference in the sizes of the two countries.

The evidence on the excess of the average social rate of return to R&D over private returns in the U.S. is quite strong. Mansfield et al. (1977) found the median social rate of return from seventeen industrial innovations to be 56 per cent, while the corresponding median private rate was only 25 per cent. The difference between the social and private rates of return was significantly higher for product innovations and appeared to be greater for more important product innovations. Similarly, the studies by Scherer (1982a,b), Griliches (1980) and Griliches and Lichtenberg (1982), cited previously, indicated a similar order of excess social over private rates of return to R&D. In particular, Scherer's study indicated that most of the excess of social over private returns arose from benefits conferred on users of product innovations.

On the face of it, these measures support the presumption that insufficient private incentives for R&D indicate a need for government support. However, there are two major problems with this conclusion. First, the evidence indicates a large excess of *average* social returns over private returns, but the measure relevant to public policy is the excess of *marginal* returns over private returns. It is difficult to determine whether the average excess indicates that such an excess exists at the margin. Indeed, Mansfield's (1968) evidence suggests that the average excess is greater for more important innovations than for less important ones. Because less important innovations are also generally less privately profitable, they would seem to be more representative of marginal R&D investment, suggesting that the excess of social benefits over private benefits may be smaller at the margin than on average.

A more important problem arises from the size difference between the Canadian and U.S. economies (Berkowitz and Kotowitz 1982). Most users of product innovations that originate in the U.S., whether other producers or ultimate consumers, are likely to be U.S. residents, which is not necessarily the case in Canada. In particular, there is a great difference between innovations that are aimed at local markets – mainly adaptations of foreign technology – and those that are export-oriented. Because the excess of social benefits over private benefits arises mainly from the inability of the innovator to appropriate the benefits of the innovation in the form of higher product prices, these net social benefits will accrue mainly to users of the products. In the case of exports, these users are mainly foreigners. Unless the Canadian government is for some reason concerned with the social welfare of foreign residents, there is therefore likely to be a fairly close identity between domestic social and private returns for exported goods and little justification for government support.

Where customers are local, however, the inability of the innovator to appropriate the benefits of R&D will result in a greater discrepancy between social and private returns. Government support may therefore be warranted in these cases. As was noted earlier, however, R&D aimed at the domestic market generally seeks imitations of innovations, if locational advantages justify domestic production, and adaptations of innovations to meet domestic needs. Thus it is the lowly imitative R&D that is most likely to yield net social benefits, not the innovative, export-oriented R&D that is so highly touted by many proponents of positive industrial strategy.

The magnitude of optimal support for such R&D is obviously not uniform. It depends not only on the excess of social over private returns in each case, but also on the rate at which this difference declines with increased R&D and on the rate of decline in the overall marginal productivity of R&D. It is, therefore, extremely difficult to evaluate, as is suggested by the very different responses of private R&D to government incentives indicated by the research of Palda and Pazderka (1982) and Choudhry, Cohen, and Saunders (1981). Uniform support rates are thus unlikely to be socially efficient.

In principle, therefore, government should support R&D in a discretionary manner. Yet in practice the government is most unlikely to possess the extensive information it would need in order to apply differential rates optimally. Indeed, the quality of information and judgement necessary to apply a discretionary policy in an efficient manner in all probability simply cannot be available to governments. On the whole, the high costs of collecting and processing relevant information and of administering support programs imply that support for R&D should be administered in a relatively simple manner and with little discretion. Nevertheless, as was argued earlier, uniform support across all industries, firms, and types of innovation may be costly and inefficient.

Some guidelines for the choice of industries in which to concentrate support may be obtained from a consideration of the likely effects of industry structure on the ability to appropriate R&D benefits. As the earlier discussion of pre-emptive R&D revealed, process R&D performed by incumbents in a concentrated industry with high entry barriers is conducive to private appropriation of the benefits from R&D; consequently it is likely to generate little net social welfare. Moreover, in established consumer product industries in which the advantage of priority is large, innovators can again generally appropriate the benefits, and again the result is little net social welfare. In these situations a large subsidy is probably not optimal. Similar arguments hold for industries in which patent protection is relatively effective.

The main deficiency in private R&D investment is therefore likely to occur in competitive industries selling to Canadian customers where patent protection is weak. Because imitation is rapid in such industries, the benefits of innovation cannot easily be appropriated by the innovator. Each firm is thus likely to refrain from investment in R&D in the hope of 'free riding' on its rivals' investment. Even when competition necessitates some form of innovation, rapid imitation results in the transfer of benefits to customers in the form of lower prices or increased quality, so that the social returns to Canada from such innovation are likely to exceed the private returns. In other words, even where there is R&D and related innovation in such industries, there is likely to be less such investment than is socially desirable. Where firms are small, this problem may be exacerbated to the extent that there are economies of scale in R&D, since R&D may be profitable for the industry as a whole, but not to individual firms within it.

Thus relatively competitive industries that serve Canadian customers and in which imitation is easy should in principle yield the highest returns from government support of R&D. To reduce duplication of effort and to achieve the greatest benefit from scale economies in R&D, such support should promote industry-wide co-operative research efforts. Such efforts may of course occur without government support and initiative, but because of the ease of free riding they involve difficult problems of organization and fund-raising. These problems can be mitigated by government financial and organizational support. Since the danger that industry-wide organizations will become co-ordinators of cartels is insignificant in competitive industries, government subsidies for this purpose should yield benefits to consumers and to society as a whole.

What form should these subsidies take? Tax concessions, a major source of government support for R&D in Canada, would be quite ineffective in promoting co-operative research. Tax concessions, whether to individual taxpayers (tax shelters) or corporations, obviously will not stimulate R&D investment unless there is a prospect of private profits from such investment. But where imitation is easy, as it is in the industries singled out in the previous paragraph, co-operative R&D efforts must operate on a nonprofit basis, disseminating the results of their research freely or at low cost. Tax concessions to individual firms are therefore not usually effective in this context. What such co-operative efforts really require are direct subsidies to industry-wide research co-operatives, although these subsidies could perhaps be supplemented by tax concessions to participating firms based on their contributions to the co-operatives.

One important problem with such organizations arises from the separation of the research group from the marketing and operational elements of the industry, a factor that tends to inhibit communications between them. There is considerable evidence (Freeman 1974) that such communication is essential to the commercial success of innovations. One way to alleviate this problem to some extent may be to vest control over such research establishments in industry rather than in government.

Export-oriented industries, even if competitive, should *not*, on this line of argument, be singled out for assistance. The benefits from innovation in these industries are likely to accrue to foreign customers, particularly when foreign competitive pressures force Canadian firms to innovate. The social benefits to Canadians will therefore be the same as the private rewards to the innovators, and there is no case for government support.

The issue of foreign ownership must also be addressed. Subsidies to Canadian firms that increase the net after-tax profits of the recipients basically redistribute income from taxpayers to shareowners (ignoring the efficiency costs of raising the money). They may thus be judged on the basis of their effects on the allocation of R&D investment. But subsidies to foreign-owned firms that increase the firms' after-tax profits involve a net transfer from Canadian taxpayers to foreigners. This transfer must be deducted from the net social gain from improved allocation of R&D in evaluating the desirability of government support.

In the case of competitive industries that serve Canadians, we have seen that most benefits from increased innovation accrue to Canadian customers. The fact that some foreign-owned firms may participate in the research effort is then irrelevant and does not alter the desirability of supporting co-operative research for the industries indicated. However, when government support is likely to increase excess profits – that is, in cases in which some degree of monopoly is present – support for R&D by foreign-owned corporations is not desirable. As was argued earlier, such support is not likely to yield high social returns even when it is given to Canadian firms.

Incidentally, the logic of the preceding argument also applies to the patent system, which is equivalent to an R&D subsidy financed by a tax on the users of the resulting innovations. Where patented products are consumed by Canadians, the patent system constitutes a subsidy by Canadian consumers to producers. Where producing firms are foreign or owned by foreigners, even foreigners producing in Canada, such transfers reduce total Canadian welfare.[10]

Our analysis thus suggests that current government support for R&D, which mainly takes the form of generous[11] tax concessions to firms and individuals on the one hand and the patent system on the other, is not likely to be optimal. These programs operate mainly by improving the private benefits from innovation. They therefore often transfer resources to industries in which the excess of social returns over private returns is relatively small and subsidize foreign producers and consumers at the expense of Canadian consumers and taxpayers.

Finally, it should perhaps be stressed that these judgements are based on a parochial view of social welfare, one that ignores both the welfare of nonCanadians and the benefits conferred on Canadians by foreign government subsidies and patents. It may well be argued that, as a member of the world community, it is incumbent on Canada to support innovation that benefits other nations, in the same way that other nations support innovation that benefits us. Basic research in universities and other institutions clearly falls within this category. However, even if one accepts this argument, it seems reasonable to weight the welfare of Canadians more heavily than that of foreigners and hence to concentrate the Canadian government's limited resources so as to maximize an appropriately weighted social welfare.

PROMOTION OF CANADIAN LEADERSHIP IN HIGH-TECHNOLOGY INDUSTRIES

The preceding analysis referred to general government R&D support. However, as the analysis in Chapter 4 of the benefits of priority suggests, the case for promoting major innovation in order to establish a strong market presence in specific high-technology growth industries may involve different strategies for government support. Owing to the massive investment required in this case, general assistance programs such as tax concessions and general R&D subsidies are not likely to be effective. If the arguments in favour of government support of such innovative efforts are valid, it seems obvious that, given limited resources, the effectiveness of government action will be enhanced if it concentrates its support on specific industries and firms, particularly on those that are sufficiently well established to compete on their own merit – those that have a head start in knowledge and market position and can take advantage of the support. Such support, if sufficiently great, may significantly increase the probability of winning by limiting the number of potential competitors.

The argument is basically that a strong *commitment* by the government will represent a credible threat to meet all competition and will therefore intimidate potential rivals and increase the probability of eventual success of the supported industry. Potential competitors will thus be limited to those supported strongly by their respective governments. Since the number of governments that are in a position to pursue such policies credibly is limited, and since each must inevitably concentrate its support on a limited number of industries, the effect of such policies is to restrict the number of potential competitors and therefore to increase the chance of winning for any participant. Moreover, government participation in these projects may help the winners to co-operate with each other in order to generate increased profits – for example, by exemption from antitrust legislation.

The problem is that if governments actually compete through heavy support of selected firms and industries, such support may dissipate the increased expected profitability of the industry through excessive government competition. The benefits of such government policies thus depend heavily on the government's limiting the amount of actual support, while maintaining the commitment to increase support should entry occur. In a way, the situation is similar to predatory pricing threats by oligopolists to deter entry by newcomers. As was noted earlier, it is far from clear how credible such threats are, particularly when the oligopoly is very loose and competition among its members is likely.

From a national point of view, the optimal policy would seem to be one of a limited national commitment of funds, combined with an allocation of property rights in special areas of R&D to nationally designated firms in order to reduce wasteful duplication. (See Kitch 1977 for a similar argument about the patent system.) As was suggested earlier, however, commitment alone seems to be insufficient, and actual support expenses may have to be very high, partly because government commitment is not necessarily irreversible – a necessary condition for threat credibility. While government's resources are large, Canadian government resources are small relative to those of competitors, and government is not immune to policy changes, particularly with changes in regime. It therefore seems rather unlikely that such government commitment would intimidate potential rivals.

Moreover, governments appear to be poor losers. Unlike firms which have no option but to cut their losses and depart, governments may stay in the game even after their champions have lost. The political need to justify past actions may increase the usual pressures on the government to support ailing industries. It can be exceedingly difficult for a government to withdraw support from a firm or industry created because of government direction. The positive industrial policy of today may well contain the seeds of negative industrial policy tomorrow. One example of this pattern may be the reluctance of the Canadian government to stop supporting the Canadian nuclear and aerospace industries, in spite of staggering losses and dim prospects. European examples are the Concorde and the British and French nuclear generation industries. Even Japan is not immune – it appears that some form of protection will be given to the steel industry, which has recently been modernized under government guidance.

A final serious problem with even a limited interventionist policy is that government must become *actively* involved. In addition to choosing the industries in which to concentrate its support, it must decide which firm to put into competition or in effect create such a firm directly, or by merger, or as a co-operative venture of several firms. Governments seem unlikely to have much expertise in making wise choices in these matters, especially since political considerations of the 'pork barrel' or regional development variety frequently intrude upon commercial decisions. Government ownership of such firms may be particularly dangerous, since unsuccessful government ventures can be protected from the appearance of failure through regulation and procurement policies.

Peacock (1980) has suggested that countries that tend to support R&D in a general way are more successful than those closely involved in the R&D effort. Germany and Japan, for example, tend either to designate industries and general areas to be supported, leaving firms in the industry to compete, or to organize a co-operative research effort by the industry, while allowing firms to compete in the commercialization of the resulting basic inventions. In contrast, France and, in particular, Britain, which have usually designated specific firms (frequently government-owned) for support, appear to have been relatively unsuccessful. In principle, a policy of limits on the number of potential competitors in major innovations via government commitment to support major R&D efforts in selected industries has some merit. In practice, however, the application of such a policy is likely to be costly and ineffective, particularly in a small country such as Canada.

Notes

1 There appears to be a general belief that a significant measure of Japan's success is a result of government planning and intervention, although there is little research to back up this belief. See Trezise (1982) for a critical evaluation of this proposition.

2 For a detailed exposition of these arguments, see Watson (1983).

3 For a detailed analysis of the reasons and consequences of such policies, see Green (1983) and Saunders (1983).

4 Note, however, that to the extent that such subsidization distorts the price structure (particularly the exchange rate), industries that do not benefit from special treatment are put at a disadvantage. This points out the difficulties of evaluating industrial policies piecemeal and ignoring general equilibrium effects.

5 See, for example, the Mansfield, Schwartz, and Wagner (1981) sample, in which 30 per cent of innovators did not take out patents.

6 Benefits from improved products may in principle increase consumer surplus of local consumers without affecting profits and wages; but this argument applies only to consumer product innovations, which are a small fraction of total innovation (see Scherer 1980).

7 Note, however, that threat of entry may induce incumbents to adopt product innovation earlier, as is discussed in more detail later in this paper.

8 See reference in note 5 above.

9 If the innovation reduces costs significantly, a monopolist will reduce his price, unless the innovation reduces the demand elasticity facing him.

10 For an extensive discussion of this problem, see Berkowitz and Kotowitz (1982), who recommend complete abolition of the patent system in Canada.

11 See McFetridge and Warda (1982) for documentation of the fact that Canadian tax incentives are extremely generous by international standards.

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